

Electronically controlled electromechanical valve

The present application claims the benefit of U.S. application serial no. 60/529,105 filed December 15, 2003.

The present invention relates to an electronically controlled electromechanical valve and to a fuel system vapor management unit comprising  
5 such a valve.

Electronically controlled valves are well known and often used in several technical fields like automotive and aircraft engine and fuel system vapor management. Such valves usually have two or three ports. Three port valves are advantageously used instead of two separate two port valves when such valves  
10 have at least one port in common, in order to have a more compact and simple design. However, such valves usually have only 2 positions (each of them connecting 2 of the 3 ports).

For instance, US patent 6,382,191 discloses a fuel tank pressure control system which includes an electronically controlled valve assembly able to either  
15 connect the fuel tank and the canister only (for tank venting during normal operation and refueling), or the canister and the engine only (for purging and burning the fuel vapors adsorbed on the canister). This system, which closes the communication between the fuel tank and the canister when the latter is connected to the engine, prevents too rich air/fuel mixtures from entering the  
20 engine and hence, prevents unburned hydrocarbons. The valve assembly used therein can either be constituted of 2 separate 2 port valves, or of only one single 3 port valve. The choice of 2 separate 2 port valves offers the advantage of being able to selectively and progressively control the purge flow, while simply turning on and off the tank venting valve. The choice of a regular, single three  
25 port valve does not allow that feature, but offers the advantage of a compacter and simpler design.

Therefore, it is an object of the present invention to provide an electronically controlled electromechanical valve, able of controlling tank  
venting during normal operation and refueling, and canister purge (i.e. recovered  
30 fuel vapors entry into the engine from the canister), which valve offers a compact and simple design while allowing at least one intermediate position for having an intermediate purge flow.

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Accordingly, the present invention concerns an electronically controlled electromechanical valve having at least three ports through which a fluid can flow and at least three different stable positions in which at least 2 ports are in fluid communication, said valve comprising :

- 5    - a stationary outer housing comprising at least three bores;
- a rotating inner section which rotates about an axis and comprises adequate bores defining with the bores of the housing, the at least three ports of the valve; and
- 10   - an electrical actuating system being controlled by an electronic controller and being able to switch the valve from one position to another by rotating the inner section about its axis.

This integrated valve is designed in a radial fashion, which allows for a simple and compact system. In addition, it allows not only the two traditional positions connecting each completely 2 of the 3 ports, but also at least an  
15   additional one, for instance allowing only partial communication between 2 of the 3 ports.

Other advantages of this integrated valve are :

- 20   • Lower Cost – This valve, which replaces 2 separate valves and associated piping system, reduces the total part count and hence, the cost of a system in which it is used.
- Quieter Product- Less noise comes from a valve that does not have to use pulse width modulation to control fluid flow, as it is the case with valves equipped with a linear solenoid actuator (the latter cycles the valve open and closed to vary the flow restriction according to the engine control unit (ECU) and this often results in undesirable noise).
- 25   • Digital Control Capability- A digitally controlled component is, in most occasions, easier to integrate into a microprocessor.

The valve according to the invention may be of any material (or combination of materials). It may be partially or totally made of metal and/or  
30   plastic(s). It preferably comprises polyacetal and may also comprise polyethylene at least in part of its surface in the case it is meant to be fixed by welding to a polyethylene fuel tank. Alternatively, it may be fixed mechanically (through a nail, screw ...) to the fuel sending unit flange.

The valve according to the invention has a stationary outer housing and an  
35   inner rotating section. The inner rotating section is generally of a substantially cylindrical shape, the axis of the cylinder corresponding to the axis of rotation of

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that part. The shape of the stationary outer housing is less critical but is generally substantially cylindrical as well. By "substantially cylindrical", it is meant that a substantial portion thereof is cylindrical, which does not exclude parts and/or appendices extending outside the generally cylindrical form (in the case of the housing, like electrical and fluid connections for instance).

5 The stationary outer housing comprises at least three openings (or bores) through which a fluid can flow and which define with adequate bores in the inner rotating section, at least three ports or passages through which a fluid can enter or exit the valve. According to some embodiments, the valve may comprise a fourth and even a fifth port allowing more fluid communication possibilities. In that case, in some position(s) of the valve, more than 2 ports may be into fluid communication.

10 The above mentioned bores and ports may have any shape and location inside the housing and the inner section. These shape and location are generally adapted to the shape and location of the fluid lines to which the ports will be connected.

15 The valve according to the invention has at least 3 stable positions, i.e. discrete positions in which at least 2 ports are in fluid communication and to which the valve switches from one to another in response to an electrical actuating system being controlled by an electronic controller. These 3 positions are advantageously such that 2 of them allow complete fluid communication between at least 2 ports and the third one allows only partial fluid communication between 2 ports. There could also be more than one intermediate position for having more than one partial flow between 2 given ports. Besides, the valve may also comprises an additional closed position, in which none of the above mentioned 3 ports are in fluid communication, and which is held by a suitable default mechanism (like a spring for instance) able to ensure that the system is sealed in the event of electrical power loss.

20 In one embodiment of the present invention, the electrical actuating system comprises at least three coils fixed on the outer stationary housing and at least one magnet fixed on the inner rotating section, the coils being coupled to a power generator which is able to energize them, i.e. to generate an electrical current and make it circulate through them, in response to a signal from the electronic controller. In that case, each position of the valve is associated with a given coil being energized and attracting the magnet to it. In some cases, depending on the geometry and/or location of the fluid lines to be connected to

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the valve, it may be advantageous to use at least two magnets in order to allow for a quicker switch from one valve position to another as well as the desired number of positions to allow for partial communication between the engine and the canister. According to another embodiment of the present invention, the electrical actuating system comprises a separate actuator (motor), placed on top of the valve, which rotates the inner section of the valve and puts it in given positions in response to a signal from the electronic controller. In this case, it may be necessary to have multiple position feedback sensors on the valve body. These sensors are used to determine the position of the inner rotating member in relation to the outer stationary member.

The use of such sensors is interesting in the event that the part is rotated by an external source (as explained above) but also, with the coils system explained earlier, in the event of a power failure, in which the orientation of the part is not remembered.

The valve described above gives good results when used in a fuel system vapor management unit of an engine (and more particularly, of an internal combustion engine), especially if used in a unit similar to the one described in the above mentioned US patent. In that case, one position of the valve ensures complete flow communication between a fuel tank and a vapor recovery system and the 2 other ones ensure respectively complete and partial communication between this vapor recovery system and the engine. The vapor recovery system is generally a charcoal canister, which adsorbs hydrocarbons from the tank through vapor vent lines allowing the tank to vent (during normal operation including filling) without sending hydrocarbons into the atmosphere. The hydrocarbons trapped in the canister are periodically routed to the engine for combustion, in an amount depending on the rotational speed of the engine and being metered with the valve according to the invention. This amount goes from zero when the engine is switched off (and when only the fuel tank and the canister are in total communication) to a maximum amount when the engine turns at a normal speed (and when only the canister and the engine are in total communication), and through an intermediate amount when the engine is turning at idle speed (and only the canister and the engine are in partial communication).

An additional feature that is often present in fuel system vapor management units is a vapor communication between the fuel tank and the filler pipe. In many cases it serves three functions. First it allows vapor in the fuel tank to be recirculated into the filler pipe and re-liquefied, thus minimizing vapor

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generation during refueling. Second, it serves as the communication path between the tank and the filler pipe during leak detection diagnostics. Finally, in a crash situation, the filler cap is often relied on for relieving any pressure incurred upon impact via an over pressure valve. For this reason as well, there  
5 needs to be an open communication between the fuel tank and the filler pipe. The use of a valve according to the present invention can solve this problem as well, provided that said valve is equipped with at least an additional port to be connected to a vapor recirculation line extending to the filler pipe.

In recent times however, there has been a push to restrict the size of the  
10 vapor recirculation line to control the amount of vapor that enters the filler pipe during refueling, thus minimizing the amount that escapes into the atmosphere. This creates a contradiction between the refueling function and the pressure relief function. Therefore, it is nowadays generally preferable to have both a vapor recirculation line with a large diameter (for unrestricted vapor recirculation  
15 to the filler pipe) and one with a smaller diameter, to have a restricted vapor recirculation flow during refueling. Alternatively, there could be only one vapor recirculation line but the access to it could be either through a port of large diameter or through a port of smaller diameter. Accordingly, in a preferred embodiment, use is made of a valve as described above which comprises at least  
20 five ports for being connected respectively to the fuel tank, to the canister, to the engine, to a passage of large diameter to a vapor recirculation line and to a passage of small diameter to the (or another) vapor recirculation line, the management of which ports to be in fluid communication being performed by an electronic controller. It may be advantageous however to at have at least 2 ports  
25 for being connected to the fuel tank in order to separate venting and vapor recirculation function, i.e. one port is meant for establishing fluid communication with the canister and the other one, with the filler pipe. In such a valve, more than 2 ports may be in fluid communication in some position(s) of the valve.

Some preferred embodiments of the present invention will be explained in  
30 more detail through figures 1 to 9. Figures 1 to 4 relate to a dual function 3 port valve which can be used in a fuel system vapor management unit both for venting of the fuel tank during refueling and normal operation, and for purging the canister. Figure 5 pictures an entire vapor management system using this valve. Figures 6 to 8 relate to a 3 function 6 port valve ensuring besides venting  
35 and refueling, also the vapor recirculation function. Figure 9 pictures an entire vapor management system using this valve.

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The basic components of the valve according to the first embodiment are shown in figure 1. These components comprise a stationary outer housing (1) and an inner rotating section (2), that rotates about an axis (9). The stationary outer housing has three ports. The large port (3) is in fluid connection with the vapor recovery canister. The port that exits out the side of the valve (4) is in fluid connection with the engine intake manifold. The port that exits out the bottom of the valve (5) is in fluid connection with a liquid vapor separator that is in fluid connection with the fuel storage tank. There is a movable fluid path (6) contained in the rotating inner section (2) which has 3 bores (1 on each end of the cut shown (6')), perpendicular to said cut, and one in said cut (6'').

In the position shown in figure 1, the moving path (6) creates a fluid communication between an engine intake manifold and a vapor recovery canister of a fuel system vapor management unit. The rotating inner section (2) is positioned in this orientation by energizing the first of three coils (7), and attracting one of the two fixed magnets (8) to it (the one adjacent to it).

Figure 2 shows the valve in a closed position, leaving no fluid communication between any of the ports. This position is held via a spring (not pictured) that ensures that the system is sealed in the event of a power loss. In addition, this position will be used during driving to prevent fuel from contaminating the vapor recovery canister.

Figure 3 shows the valve positioned such that there is fluid communication between the vapor recovery canister and the fuel storage tank. This position is held by energizing the circled coil and attracting the magnet adjacent to it, just as in figure 1.

Figure 4 shows the valve positioned such that there is restricted fluid communication between the vapor recovery canister and the engine intake manifold. Again, this position is held by energizing the circled coil and attracting the magnet adjacent to it.

Figure 5 shows a diagram of an entire vapor management system, including the valve pictured in figures 1-4 (9), a fuel storage tank (10), an engine intake manifold (11), a vapor recovery canister (12), fluid communication lines (13), and fluid communication between the valve (9) and the fuel storage tank (10) via a liquid/vapor discriminator (14). In addition, an electronic communication line is shown (15). This line may be used to receive signals from the engine control module specifying a valve position, which are then processed by an integral signal conditioner on the valve. The communication line

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shown (15) could also consist of a number of power sources and a ground to energize the appropriate coils to make the valve function properly. A third scenario for the communication line (15) is where it would connect to a separate fuel system processor. A one-way check valve (not shown) may be necessary  
5 between the engine intake manifold and the valve to eliminate the possibility of back flow on engine deceleration.

The valve of the second embodiment shown in figures 6 to 8 also has 4 positions like the one of the first embodiment, three of which are shown. It comprises elements similar to those the valve according to pictures 1 to 4,  
10 bearing the same numbering (but not all of them being shown), plus additional ones : one port of a large diameter (10) to a vapor recirculation line, one port of a small diameter (11) to the vapor recirculation line and one additional port to the fuel tank (12); it also comprises an additional moving path (13) for connecting the fuel tank port (12) to either of the vapor recirculation ports (10)(11).

15 Figure 6 shows the valve positioned such that there is fluid communication between the vapor recovery canister and the fuel storage tank. This position is held by energizing a coil and attracting a magnet adjacent to it (both not shown). In this position, the vapor recirculation line is in restricted communication between the tank and the filler pipe to control the amount of vapor that is  
20 reintroduced to the filler pipe during refueling.

Figure 7 shows the valve in a "closed position", which in this case means: leaving no fluid communication between the fuel tank, the canister and the engine intake manifold. However, in this position, there is full communication between the fuel tank and the filler pipe through the large diameter vapor  
25 recirculation line in anticipation of leak diagnostics or a crash situation. This position is held via a spring (not pictured) to ensure that the system is sealed in the event of a power loss. In addition, this position will be used during driving to prevent fuel from contaminating the vapor recovery canister.

Figure 8 shows the valve positioned such that there is fluid communication  
30 between the vapor recovery canister and the engine intake manifold. In this position, there is no fluid communication between the fuel tank and the filler pipe. This position can be varied (just as shown in the first embodiment, by the use of at least an additional coil providing at least one intermediate position) to adjust for the amount of purged vapor the engine can handle at a given time.

35 Figure 9 shows a diagram of an entire vapor management system, including the valve pictured in figures 6-8 (1), a fuel storage tank (2), an engine

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intake manifold (3), a vapor recovery canister (4), fluid communication lines (5), the fluid communication between the valve (1) and the fuel storage tank (2) being made via a liquid/vapor discriminator (6). A vapor recirculation line (8) is shown to be in vapor communication with the fuel storage tank (2) and the filler pipe (9) selectively based on the valve position. In addition, an electronic communication line is shown (7). This line may be used to receive signals from the engine control module specifying a valve position, which are then processed by an integral signal conditioner on the valve. The communication line shown (7) could also consist of a number of power sources and a ground to energize the appropriate coils to make the valve function properly. A third scenario for the communication line (7) is where it would connect to a separate fuel system processor. Note that a one-way check valve may be necessary between the engine intake manifold and the valve to eliminate the possibility of back flow on engine deceleration.